Status of Aquifer Impacts from Navy Red Hill Contaminant Releases (fuel & perfluorinates)

Hawaii Department of Health & U.S. EPA

Prepared for:

The Red Hill Subject Matter/Stakeholder Discussion Group

July 2023

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High-Level Summary

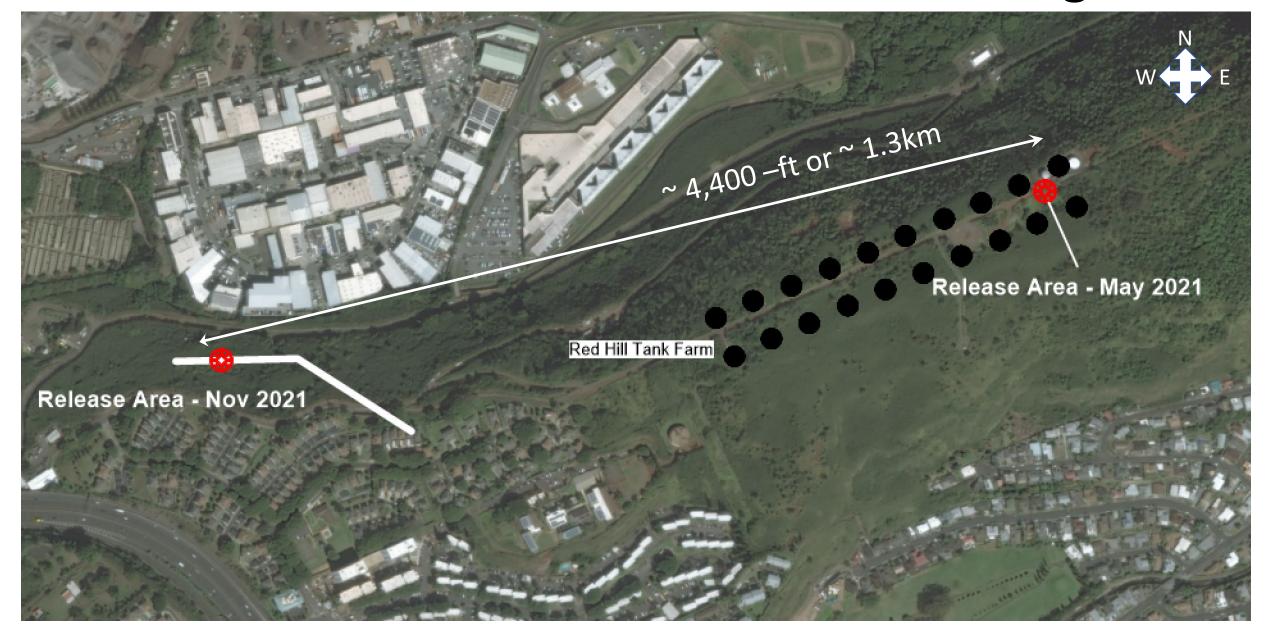
- Long history of releases
- Data showed subsurface impacts prior to AOC Tank 5 release
- Residual impacts from past releases were still present in 2021
- May and Nov 2021 releases differed in character, response, risk
- Frequent (NOI) data, GC analyses, and other forensics show that TPH concentration changes are complex
- Regardless of cause(s), peaks from 2021 releases have passed
- Further work is needed to understand transport, fate, and risk, in response to past releases and for long-term decision-making

Key Topics



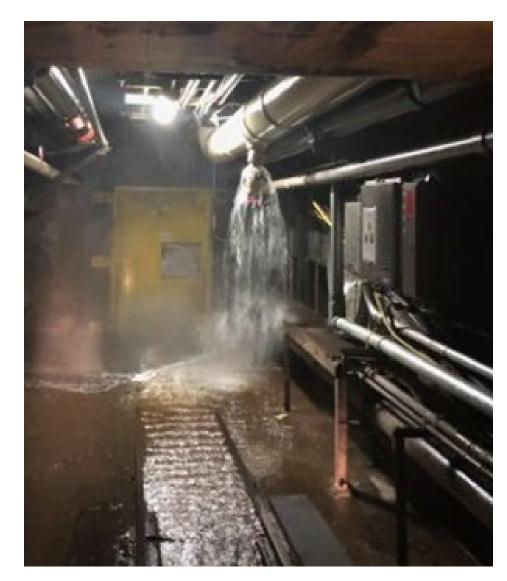
- Release events 2021 & prior
- Data observations/implications after 2021 releases
 - Apparent rates/distances of fuel migration
 - Expansion of detections, followed by contraction
- Unusual aspects within these observations
 - Engagement of non-JP5 impacts, including pyrogenic PAHs
 - Petroleum impacts in all directions
 - Deep v. shallow impacts & variability in transport
 - Vapor impacts as indication of fuel transport
 - Likely emulsification of fuel
- Recent overall aquifer conditions
 - Impacts above EALs are limited & beneath Red Hill
 - Distal impacts and those at Red Hill Shaft have abated
 - Within all observations, there are uncertainties

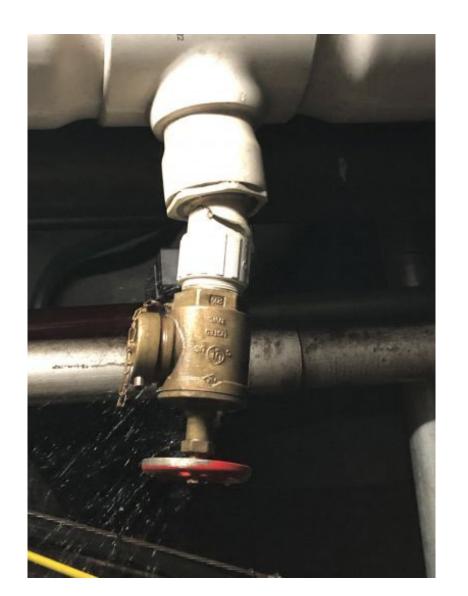
Release Locations – One release with two stages



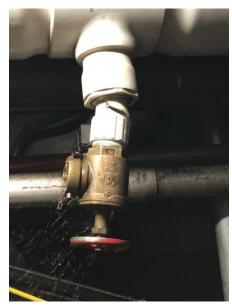
Both 2021 Releases were Into Facility Tunnels

(source: Civil **B**eat, 2022)



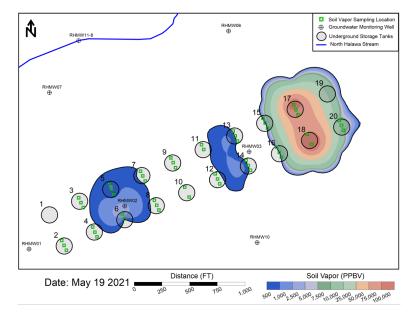


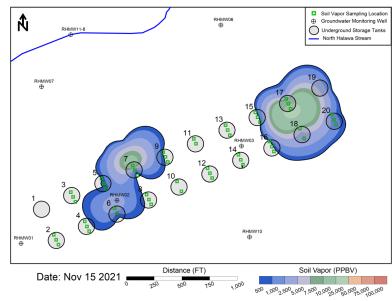
Key Observations of the Navy Release Investigation

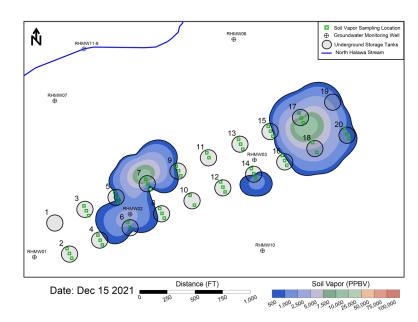


- The May release due to a pressure surge:
 - Fuel pipes ruptured at gaskets, T18 T20 area
 - JP5 poured onto tunnel floors
 - 20,957 total lost, some recovered, most went to AFFF system
 - Net 5,542 gallons were not recovered, presumed lost to ground
 - Cannot distinguish amounts in May v. Nov stages
 - Original reporting was net ~40 gallons lost to ground in May
- Fuel in the AFFF system was released on Nov 20, 2021
 - JP5 again poured onto the tunnel floor, this time in Adit 3 area
 - This is directly above Red Hill Shaft, base water supply
- Fuel from this stage of the release entered RHS
 - And was subsequently distributed into part of the Navy DWS
 - Fuel appeared to be emulsified (Navy divers & photo reports)

Soil Vapor Detections around 2021 releases







May 19, 2021

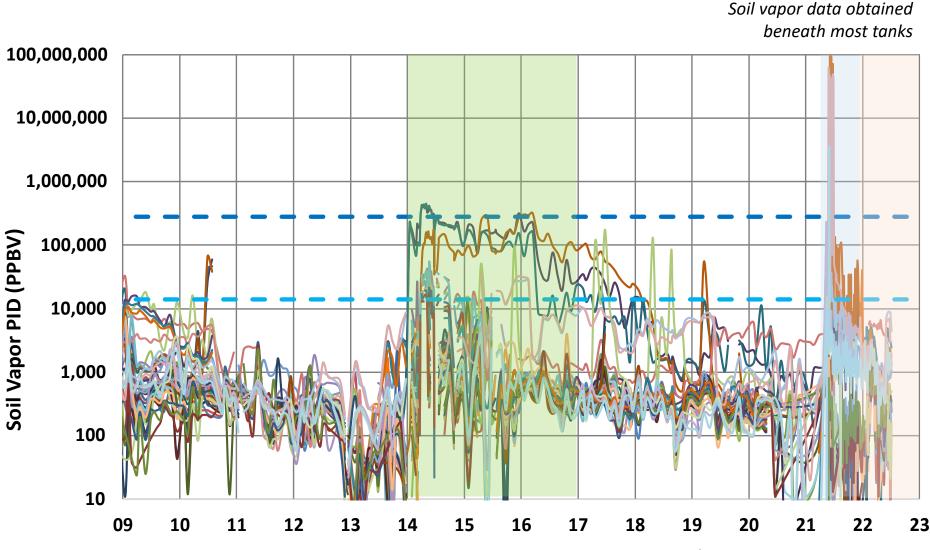
November 15, 2021

December 15, 2021

Vapor Data as Release Indications

Post-2014 release period
Post-May 2021 release period
Post-Nov 2021 release period

- 2021 releases and transport appear very different to 2014
- 2014 release:
 readings close to PID
 standard for JP-5,
 and persisted for
 multiple years
- 2021 release: far above JP-5 PID standard, but dropped rapidly

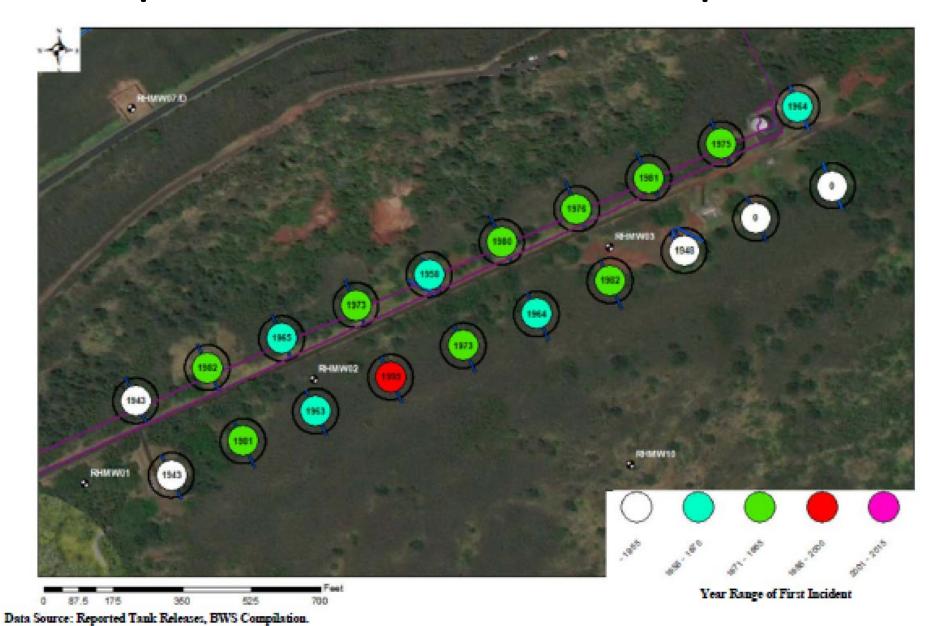


Long history of Red Hill releases

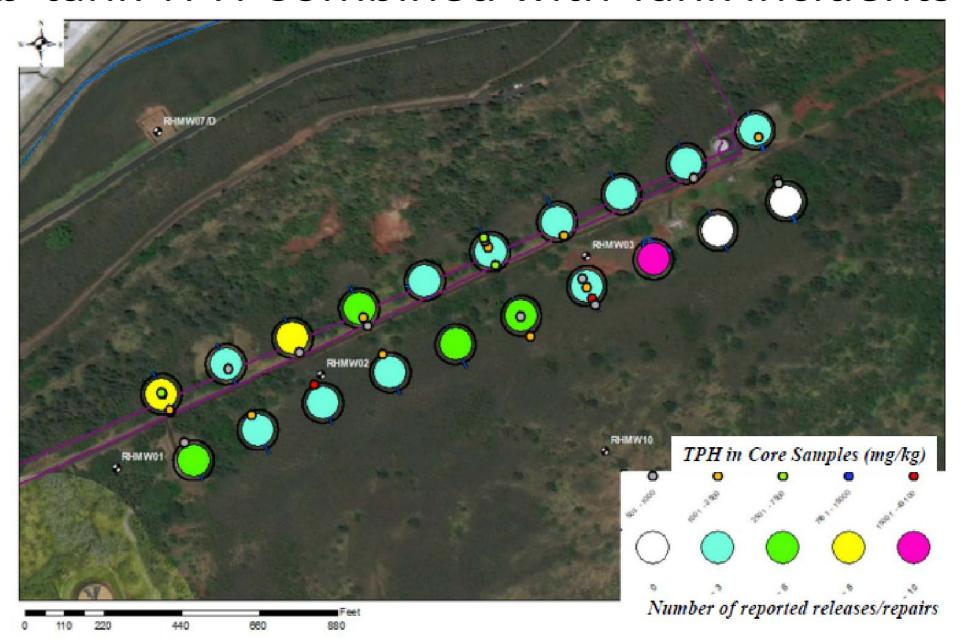


- Some tanks have leaked since filling (e.g., Tanks 1 & 19)
- Mid-1940s, 1.3-million gallon release in Adit 3 tunnel
- In 1948, Red Hill Shaft was shut down due to diesel impacts
 - Reportedly due to 25k diesel fuel supply tank release
 - Shaft was returned to service a few months following
- Beyond above, ~200,000 gallons in estimated losses
 - Only includes those quantified, about half are not
 - And this does not include chronic losses (~5,800 gal/yr)
 - Roughly >2 million gallons known lost over time
- Fuel needs/grades have shifted over time
 - Early on, mostly Navy special fuel oil (heavy marine fuel)
 - Moving to generally lighter jet and marine diesel over time
 - Old release would have much different chemical makeup

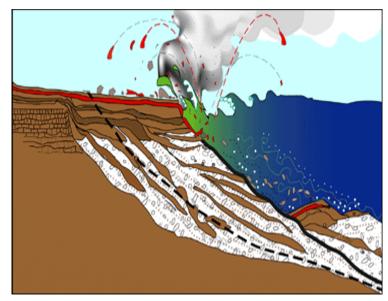
Year of reported first release or repair incident



Sub-tank TPH Combined with Tank Incidents



A Few Key Items for Technical Consideration

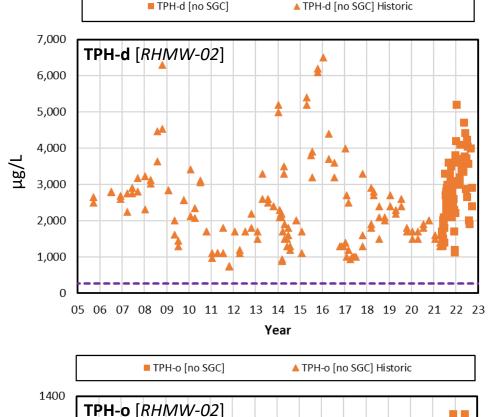


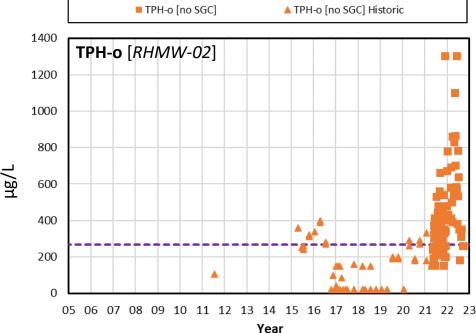
source, USGS, Kilauea Delta Formation

- TPHo first-ever exceedances in RHS
- Unusual GCs (not JP5) & migration patterns
- TPHd engaged and extended through network
 - Mostly after the November stage of release
- PAHs detected in the RH network
- CF&T itself vadose, g.w., enhancements?
- Overall, plumes appear to be diminishing in size, frequency and magnitude of detections

TPH at RHMW-02

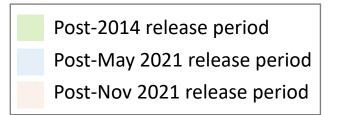
- Historical data dominated by diesel-range impact and little oil-range impact
- Data following May 2021 show a very different character, with high oil-range concentrations
- Data following May 2021 demonstrate previously unseen correlation of oil and diesel range TPH at some wells

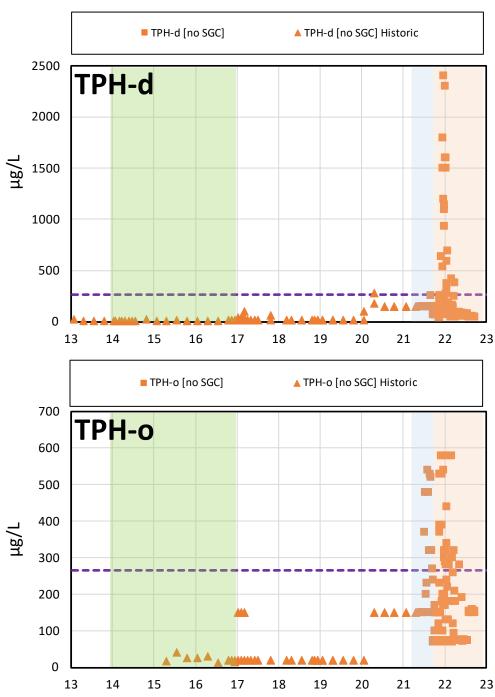




TPH at RHS

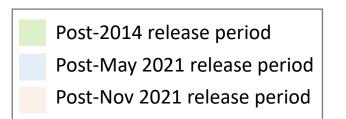
- RHS historically demonstrated few impact
- This changed in 2021 with oil and diesel range impacts:
 - Concentrations of both ranges exceeded EALs (*EALs changed in 2022*)
 - Concentration ranges and timing differ for the oil and gasoline ranges

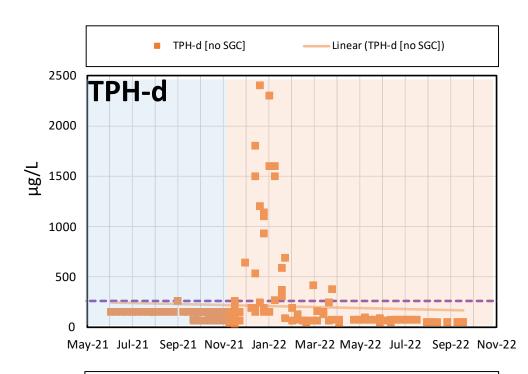


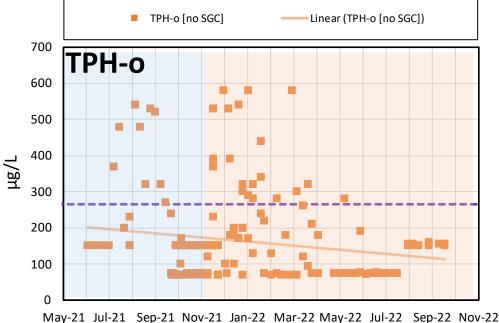


TPH at RHS

- RHS impacted by oil-range but not diesel range following May 2021
- RHS impacted by diesel-range following the November 2021:
 - Oil-range may have also increased but also possibly just persist from May







Support for Limited Risk – Releases to Date



source, Hawaii News Now, Dec 16, 2021

Looking for water agency SMEs perspectives on conditions

Informs potential hazards and actions needed

- Red Hill Shaft below EALs
- Saprolite wedge & caprock CF&T impedance
- Stable & contracting fuel/related impacts
- Absence of historic impacts to receptors
- Red Hill/Hawaii aquifer exhibits apparent buffering
- Despite this, elevated TPH appeared more widespread during/after 2021 than before:
 - Need a clearer understanding of the cause(s)
 - Need to keep that in mind as we move forward

Most Prevalent Detected Analytes in Groundwater (PF-compounds covered subsequently)

Analyte Name	Average	Maximum	Units	# Detects
Lead	0.27	14.0	ug/l	1196
Total Organic Carbon	1,342	25,000	ug/l	1071
C10-C24 Petroleum Hydrocarbons	898	142,000	ug/l	851
C24-C40 Petroleum Hydrocarbons	317	1,400	ug/l	589
Chloroform	0.84	4.0	ug/l	250
Methane	937	6,200	ug/l	244
Chloromethane	0.32	2.0	ug/l	217
Naphthalene	15.9	110	ug/l	163
1-Methylnaphthalene	10.2	53.0	ug/l	159
Total Extractable Hydrocarbons	912	5,852	ug/l	118
2-Methylnaphthalene	9.4	49.0	ug/l	115
Acenaphthene	0.14	0.69	ug/l	113
C6-C10 Gasoline Range Organics	24.9	159	ug/l	93
Fluorene	0.10	0.26	ug/l	89
Bis(2-ethylhexyl)phthalate	5.3	118	ug/l	73
Xylenes, Total	0.41	7.2	ug/l	61
Ethylbenzene	0.16	0.63	ug/l	60
o-Xylene	0.33	4.4	ug/l	58

Total Petroleum Hydrocarbons – Diesel Range (TPHd)



Prior to 2021 Release



Late 2021 – after release



April 2022



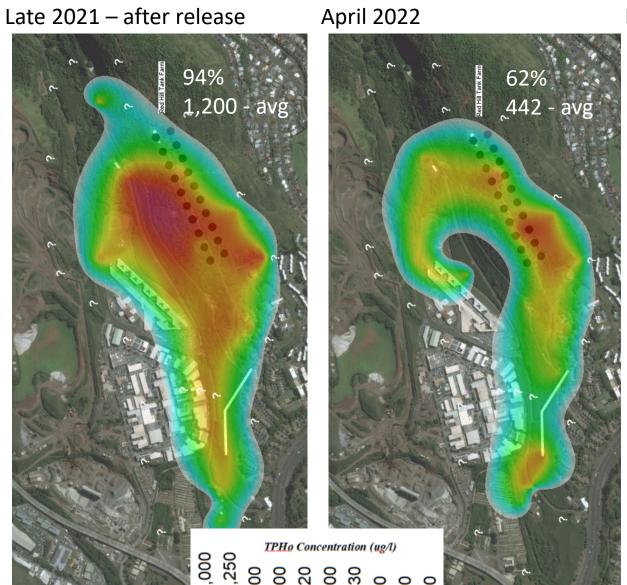
Early 2023



Total Petroleum Hydrocarbons – Oil Range (TPHo)







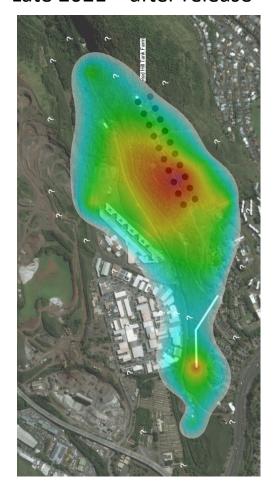


Detailed Analyses of Time-Series and GCs: Contributing Factors

Apparent Changes in Mapped Extents

- Maps integrate (i.e., interpolate) changes seen in time-series sample data at individual wells.
- Need to therefore understand these data.

Late 2021 – after release

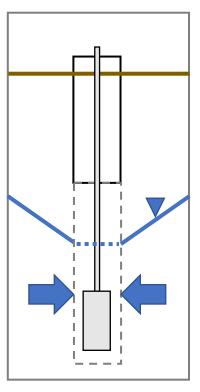


Early 2023

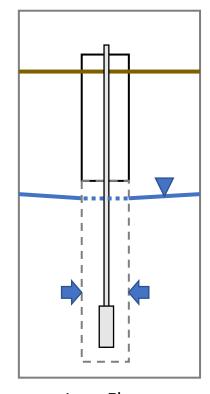


Changes to Sampling Methods

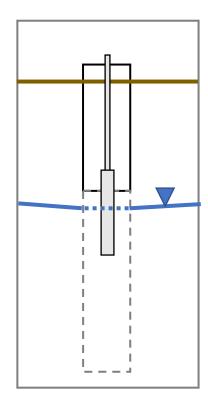
- Sampling methods vary between low-flow and bailer methods
- The methods provide similar indications of the presence of contaminants.
- However, concentrations can systematically differ between methods.



Traditional: large purged volume, induces turbidity.



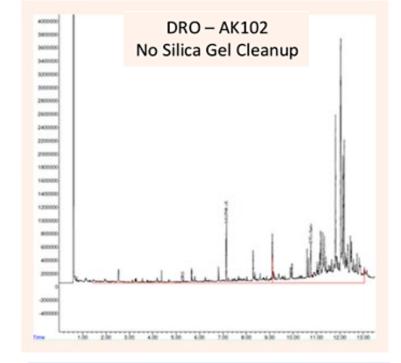
Low-Flow: minimal drawdown and turbidity.



Bailer: incidental drawdown, can straddle water table and sheens

Silica Gel Cleanup: SGC

- From 2017, some TPH samples subject to SGC:
 - Petroleum biodegrades into hydrocarbons and polar metabolites.
 - SGC is used analysis to adsorb polar metabolites.
 - The difference in concentrations can indicate fuel biodegradation.
- Some metabolites are toxic, so care is needed interpreting results.



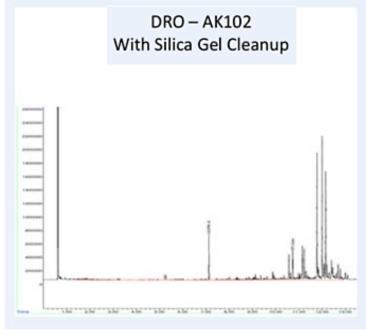
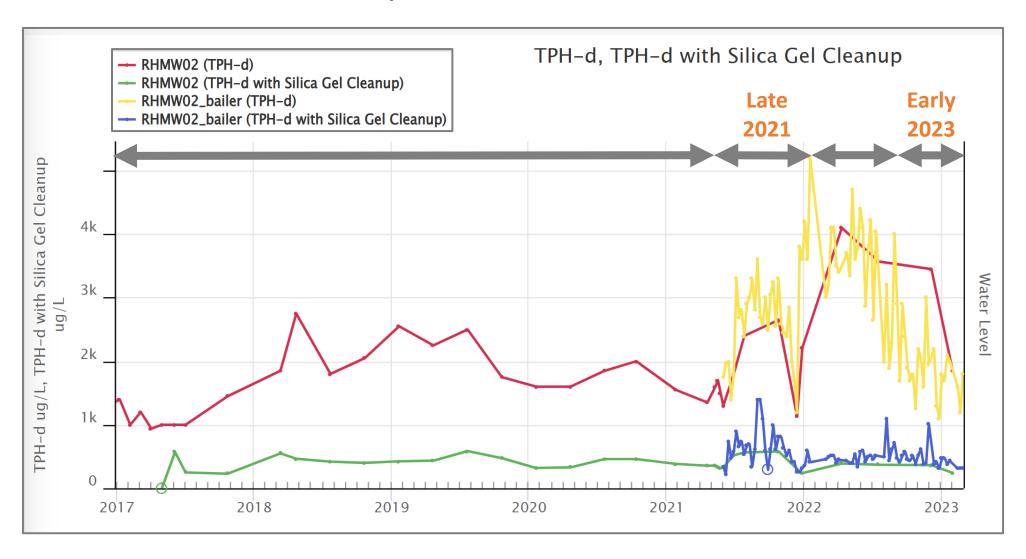


Figure modified from Figure 5-2 "Effects of sample cleanup on the quantitation of hydrocarbons in environmental samples" *from* Interstate Technology & Regulatory Council (ITRC). 2018. TPH Risk Evaluation at Petroleum-Contaminated Sites. THPRisk-1. Washington, D.C.: ITRC, TPH Risk Evaluation Team. https://tphrisk-1.itrcweb.org

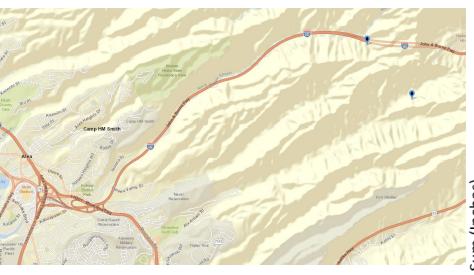
Time-Series Example: RHMW-02



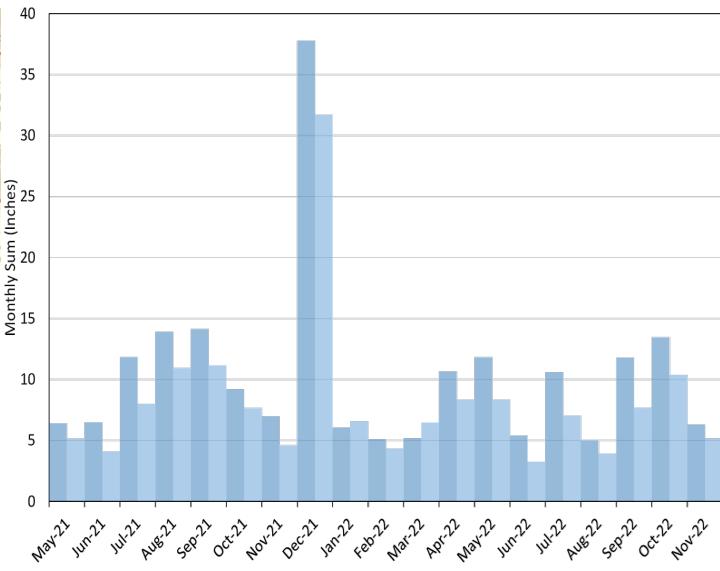
Possible Effects of Water Levels and Precipitation

- Effect of water levels & precipitation on concentrations can be important to discern:
 - So that apparent breakthrough is not misinterpreted as migration
- Data analyses 2014-to-2020 did not show relation between TPH and water levels or precipitation:
 - Data may have been too infrequent
- NOI data provide frequent TPH and water level data which include:
 - Large winter 2021 precipitation events
 - Water level rebound from shut-down of RHS

Monthly Precipitation from Nearby Stations



Fit to TPH-d using water levels, precip, and an offset, weekly precip, and log transform on precip

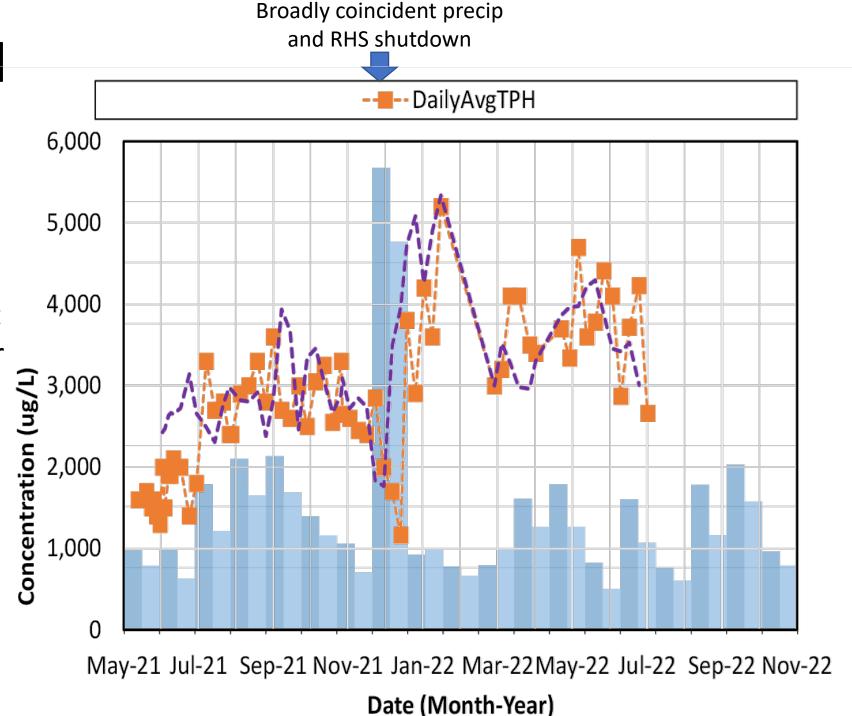


RHMW-02 TPH-d

- TPH response may be influenced by precipitation and water level changes somewhat consistent with a "smear zone"
- TPH-d fit at RHMW-02:

TPH = A + B(
$$ln[P]$$
) + C($ln[\Delta WL]$)

Lagging improves fit



GW Chemistry post-May 2021: Summary #1

- Most signatures are inconsistent with fresh JP-5, except RHMW2254-01 following November 2021
- RHMW02 signature is consistent with biodegradation of JP-5 (or similar) fuel
- Consistency of RHMW02 signature and concentration range suggests common source material nearby that pre-dates 2021
- Interpretation of TPH-o following May 2021 is complicated by lab irregularities, poorly resolved peaks. But, inconsistent with fresh JP-5:
 - Dominated by diesel-range Unresolved Complex Mixture (UCM) extending into oil-range → biodegradation of diesel-range hydrocarbons

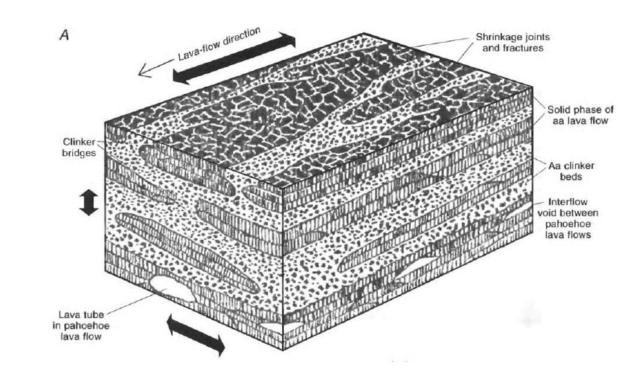
GW Chemistry post-May 2021: Summary #2

- TPH concentration changes probably result from several factors:
 - "True" breakthrough of mobile, newly-released, fuel
 - Remobilization of old fuel near the water table (via water level fluctuation)
 - Remobilization of old fuel in the vadose zone (entrained / displaced by infiltrating water)
 - Presence of fuel additives, cleaning products, and other unresolved peaks
- Comparison (differencing from) to historical data is challenged by:
 - Changed (greatly increased) frequency of sampling
 - Changes methods of sample retrieval (bailer vs low flow vs traditional)
 - Changes in labs and use of SGC vs non-SGC results

Hydrogeology and Implications for Source(s) of Water to RHS

Geology, Tanks, and Tunnels

- Aquifer comprised of a sequence of stacked basalt lava flows
- Lavas flowed generally from the northeast toward the southwest
- Geologic fabric affects the directions and rates of groundwater and fuel movement



Basal Aquifer Heterogeneity

- Although the basalts collectively form a major regional aquifer system, the ancient lava flows that produced it create a meandering pattern of local aquifer units:
- Complicated and compartmentalized

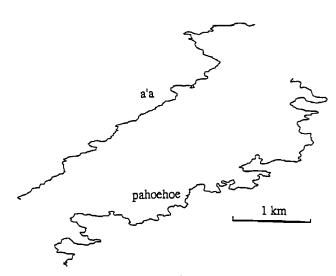
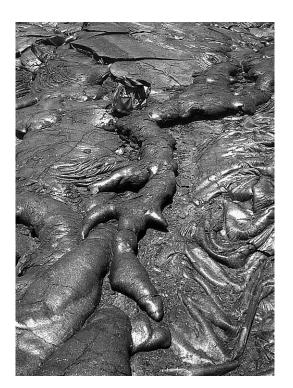
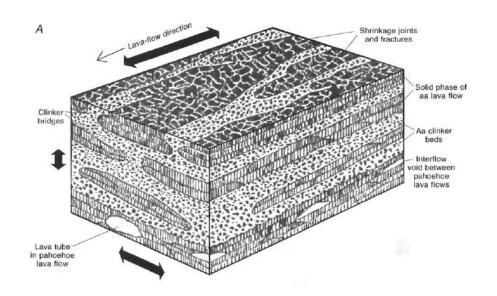


Fig. 2. Digitized outlines of a'a and pahoehoe flows. Typically, pahoehoe margins have more embayments and protrusions, corresponding to a higher D.

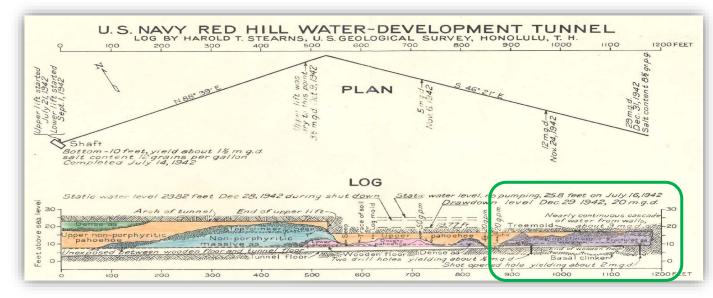


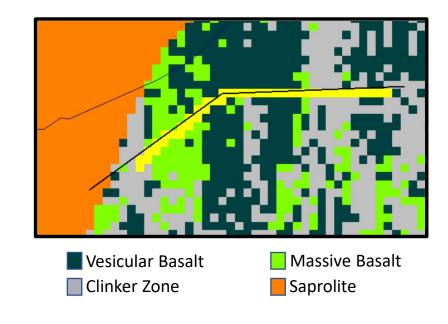


Hydraulic Containment or "Capture" - Backup



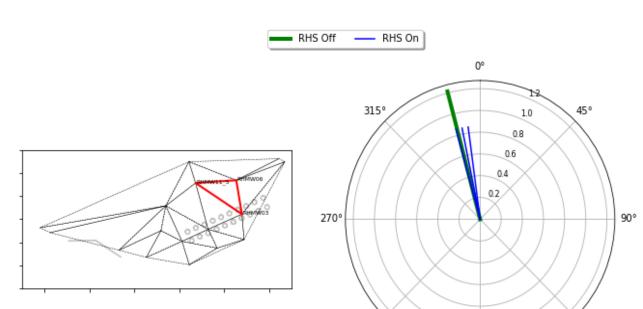
- The aquifer is complex, and the movement of groundwater and NAPL is non-ideal
- RHS tunnel intercepts "zones" of different material, and draws water and contaminants in complex patterns





Gradients and Mapped Elevations: Summary

- Pumping RHS lowers heads, reduces some gradients, has little effect on directions.
- Adjacent triangles often have contradictory gradients, unaffected by pumping.
- Gradients away from RHMW15, even when RHS is on, suggesting source of water to RHS may be deeper?

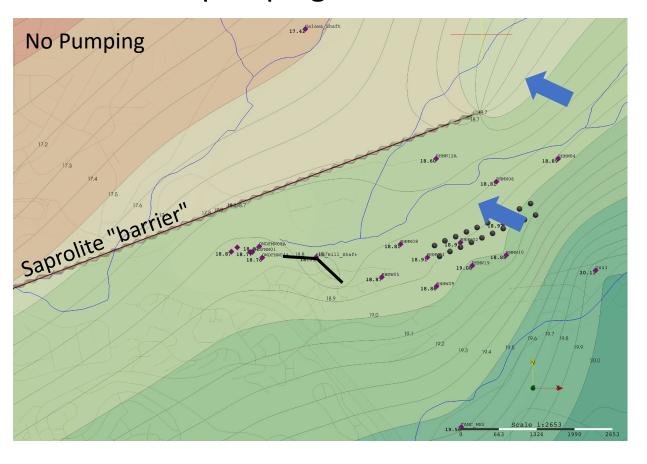


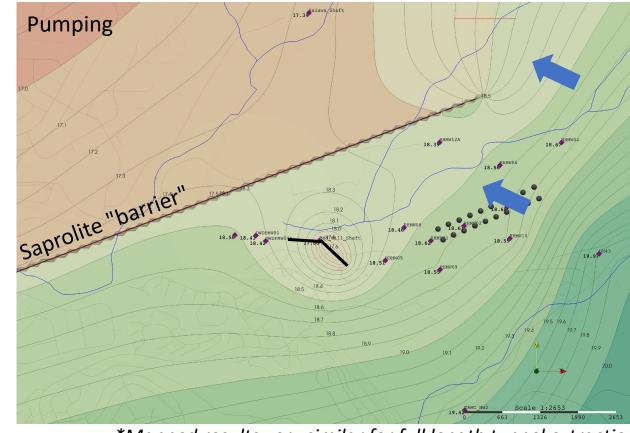
Three-Point Gradients (Observed 2022) 8

	RHS Off	RHS On	
Azimuth	345.3	348.5	
Magnitude (Ft/Mile)	1.2	0.9	
Number of Observations	1	3	

Water Level Mapping and Hydraulic Gradients

- Water levels mapped to approximate the effects of pumping at RHS and presence of saprolite below the water table
- Extent of pumping influences and zone of contribution unclear





*Mapped results very similar for full length tunnel extraction

Source(s) of Water to RHS and Hydraulic Capture

- Water levels do not clearly identify sources of water to RHS:
 - The efficacy of RHS as a containment-recovery device is questionable
 - The potential for long-term impact to RHS from "typical" tank farm releases is uncertain
- TPH-o impacts at RHS after May 2021 suggest at least some water and contaminants from the tank farm can reach RHS – however:
 - The appearance of TPH-o at RHS soon after May 2021 is fraught by unknowns – the compounds detected, their relation to the May release, plausible transport pathways, and so on
 - Reliable conclusions cannot yet be drawn about transport mechanisms.

Discussion

- Further work is needed to understand transport, fate, and risk, in response to past releases and for long-term decision-making.
- Thoughts?